The Effects of Processing and Aging on the Thermal Conductivity of Polycrystalline Silicon Films

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Polycrystalline silicon is widely used in microelectromechanical systems (MEMS) due to its integration compatibility with CMOS devices and attractive material properties. For MEMS devices that require thermal dissipation or thermal management to ensure functionality, heat conduction in polycrystalline silicon becomes a primary factor in their design and reliability. Thus, thermal conductivity data for polycrystalline silicon as function of temperature, processing conditions, and aging are necessary to design, predict, and improve the performance of these devices.

In this work, the effect of processing and aging on the thermal conductivity of polycrystalline silicon films is presented. Polycrystalline silicon films were deposited on thermally oxidized silicon wafers in an LPCVD furnace with varying deposition temperatures. The films, on the order of 1 μm in thickness, were annealed in a nitrogen environment at 1100°C for 3 hours. The lateral thermal conductivity was measured on free-standing films between 70 –320K using steady-state electrical resistance thermometry. Extended exposures to temperatures up to 800°C were performed on a limited number of samples to investigate the effects of aging on both grain growth and thermal conductivity. Microstuructral analysis was performed using TEM to provide data on the grain structure post annealing and aging exposures. Finally, the effect of microstructure on the thermal conductivity was modeled using an approximate solution to the Boltzmann transport equation employing a relaxation time approximation including grain boundary scattering. Both experimental data and modeling results are presented to elucidate the relative importance of phonon-grain boundary scattering in limiting the thermal conductivity in polycrystalline silicon films.